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VOLUME REDUCTION AND BIOLOGICAL STABILIZATION OF SLUDGE IN SMALL SEWAGE PLANTS BY SOLAR DRYING

M. Bux,[1] R. Baumann,[1] S. Quadt,[2] J. Pinnekamp,[2] and W. Mühlbauer[1]

[1]University of Hohenheim, Institute for Agricultural Engineering in the Tropics and Subtropics, Garbenstraße 9, 70599 Stuttgart (FRG)
[2]University of Stuttgart, Institute for Sanitary Engineering, Water Quality and Solid Waste Management, Bandtäle 2, 70569 Stuttgart (FRG)

ABSTRACT

High investments, high dumping costs and high electrical energy consumption turn waste water treatment in small sewage plants an expensive process. Therefore, the University of Hohenheim and the company Thermo-System have developed a fully automatic low temperature solar drying plant allowing further stabilization and volume reduction of sewage sludge by continuous mixing and aerating. To test the potential of the technology, the drying process was investigated in a commercially operated municipal sewage treatment plant with aerobic sludge digestion. During experiments, the changes of the dry solids concentration and the volatile solids, the climatic conditions and the energy consumption were constantly measured and documented. It was found, that the sludge could be dried from a dry solids

concentration of 3 to 93% w/w in 64 (flocculated) or 83 days (non-flocculated). At the same time, the volatile solids content was reduced from 65 to 34% w/w, respectively. The electrical energy consumption was only 22 to 28 kWh per ton of evaporated water, compared to 70 to 110 kWh required for conventional drying processes. The thermal energy for evaporation was fully covered by solar energy.

Key Words: Drying; Flocculant; Sewage sludge; Volatiles

INTRODUCTION

End product of any waste water treatment process is the cleaned water and a more or less fluid sewage sludge. This sludge has to be biologically stabilized to reduce odors and pathogens, improve its handling and allow a controlled dumping. The stabilization is usually done by an aerobic or anaerobic digestion process. While aerobic digestion is widely used in small sewage plants, anaerobic digestion is applied in larger ones since investments are considerably higher. Aerobic digestion causes, however, high operation costs due to the high consumption of electrical energy for aeration and mixing of the sludge. To treat one cubic meter of the sludge, usually 50–100 kWh are required in the aerobic process, compared to 5 kWh for the anaerobic process (1). A further problem of small sewage plants is the management of temporarily changing quantities of waste water. The relatively large aeration tanks leading to higher capital costs or an incomplete stabilization have to be accepted as an alternative.

Other problems are the large volume of the liquid sludge and hygienic aspects. Both are limiting the possible pathways of disposal. Therefore, different processes to achieve a reduction in volume and an improvement of the characteristics are applied (2). Mechanical dewatering by pressing or centrifuging reduces the water content to 70–80%, but there is neither a stabilization nor a reduction of pathogens. Furthermore, the required investment for the equipment and the infrastructure is considerable. Thermal drying as a follow-up process can raise the dry solids concentration from 30 up to 90% w/w, stabilize the sludge and destroy pathogens. However investments, operation costs and energy consumption are high (3,4,5). This process is therefore suitable only for large sewage treatment plants (6).

A further possibility for mass reduction is drying of the sludge in a solar dryer. Such equipment was developed by the University of Hohenheim and the company Thermo-System. Starting in 1995 several sewage sludge

dryers of this type have been installed in German sewage plants, treating meanwhile more than 10 000 t of wet sludge annually (7). During commercial operation the technology proved to be suitable and highly cost efficient for small to medium sized sewage treatment plants. Almost no maintenance is needed, and the achieved evaporation rates per square meter were up to three times higher than in conventional sludge beds. This makes the technology interesting for small to medium sized plants in moderate climate and for bigger sized plants in warm climates. This paper shows the influence of an organic flocculant on the drying time and the influence of drying on the volatile solids.

EQUIPMENT AND METHOD

The experiments were carried out in a commercially operated solar dryer for municipal sewage sludge, developed by the University of Hohenheim and the company Thermo-System (7). Figure 1 shows the operation principle of the solar dryer.

The plant is located in a mountain region in southern Germany at a height of 900 m above sea level. The referring sewage plant is clearing the effluent of a small community with around 1000 inhabitants. This corresponds to an annual output of 500 t (wet basis) of aerobically digested sewage sludge at a dry solids concentration of 3% w/w.

The construction of the solar plant is based on an improved greenhouse construction mounted on paved flooring with lateral walls. Drainage

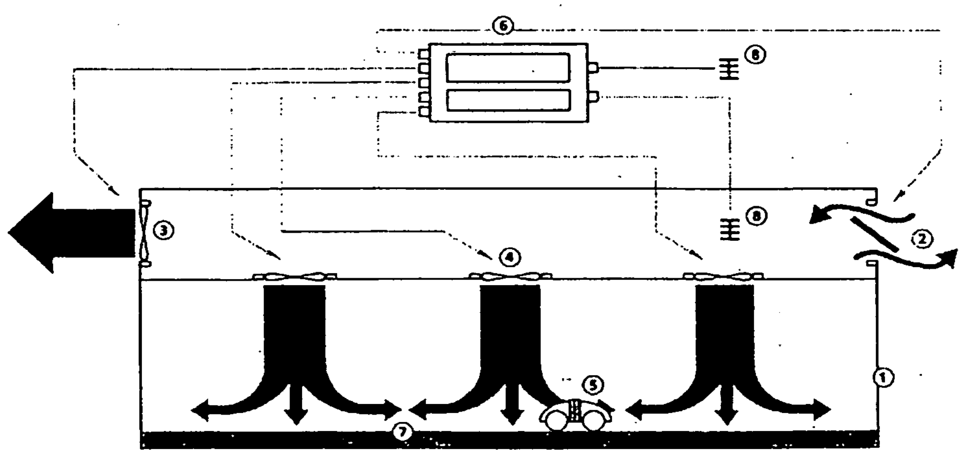

Figure 1. Operation principle of the Thermo-System solar sewage sludge dryer: (1) closed transparent cover; (2) air flap; (3) exhaust air fans; (4) ventilation fans; (5) "electric mole"; (6) microprocessor; (7) drainage floor; (8) internal/external sensors.

strips integrated in the flooring of the plant allow the drainage and filtration of the free water when liquid sludge is dried. The plant is completely enclosed by a transparent covering made of a well insulating (k-factor 3.2 $W/m^2 K$) and highly UV-stabilized three-layer air bubble foil showing a life span of more than 10 years. Due to the high mechanical strength and the special fixing system the air bubble foil withstands high wind or snow loads and provides a good transmission for the incoming solar radiation of up to 83%. The liquid or mechanically dewatered sludge is spread out on the flooring of the plant in layers of 20 to 50 cm and automatically mixed and aerated by a small robot, the so called "electric mole". The "electric mole" is about 1 m wide and 1.4 m long and has two slowly rotating axes with thin metal wheels. Each axis is equipped with different mixing tools adapted to the sludge characteristics, rotating with an individual rotation speed. Due to the controlling system based on six supersonic sensors and a microprocessor, the "electric mole" operates completely automatically and independent of the chamber geometry. Each machine controls a drying area of up to 700 m^2. During the process the sludge is mixed up to twelve times per day to assure an odor free and efficient drying during the whole process. The completely closed cover is fitted with controlled air-flappers and exhaust air fans preventing the uncontrolled exchange of air and delivering temporary large amounts of fresh air. By that, maximum advantage shall be taken from the drying potential of the ambient air, which is not dependent on the solar radiation falling directly on the surface of the plant. Indoor-ventilators mounted on the horizontal girders provide a turbulent air stream on the surface of the sludge to remove saturated surface layers from the sludge particles. During the process all relevant parameters like temperature of the sludge, temperature and relative humidity of the drying air and the ambient air, global radiation, wind speed and moisture content of the sludge are measured by an integrated microprocessor every two seconds. This microprocessor controls all components of the plant automatically.

During the experiments all described parameters measured by the controller of the plant as well as the global radiation falling on the surface of the sludge and the electrical energy consumption of all components were measured and recorded by a data logger. Furthermore, the content of the total (ds) and the volatile (vs) solids was analyzed once per week according to the usual regulations. The total solids are defined here as the residues after complete drying at a temperature of 105°C and the volatile solids as the loss of total solids after combustion at a temperature of 550°C (8,9).

During experiments, the drying chamber was separated into two identical compartments with 150 m^2 each. Each compartment was equipped with an "electric mole" but operated in the same way. Compartments 1 and 2 were filled with aerobically digested sludge at a load of 0.425 m^3/m^2.

Compartment 1 was untreated while the sludge in compartment 2 was treated with an organic flocculant (polyacrylamide) at a concentration of 4 g per kg of dry solids. The concentration was found to be suitable during a laboratory analysis of the referring sludge. Tests with a lower concentration will follow.

RESULTS

For a better understanding of the drying course the climatic conditions during the experiments are shown in Figure 2. Since the dryer is located on a height of 900 m above sea level, the temperatures are moderate even in summer. During the experiment, the daily temperature varied between 9 and 23°C, the relative humidity of the ambient air between 40 and 100%, and the solar radiation between 1.1 and 8.1 kWh/m^2 per day.

Figure 3 shows the courses of the dry solids, the volatile solids and the drying temperature. Starting at 3% the untreated sludge reached final dry solids concentration of 93% within a drying period of 83 days. Using a flocculating agent the drying time was reduced to 64 days. During the drying process, the sludge volume was reduced in both cases from 425 to 12 kg/m^2 or by 97%. This corresponds to a reduction in the annual volume from 500 to 15 m^3.

The volatile solids content of the sludge treated in the solar dryer was 65% w/w at the beginning. At the end of the drying period the content

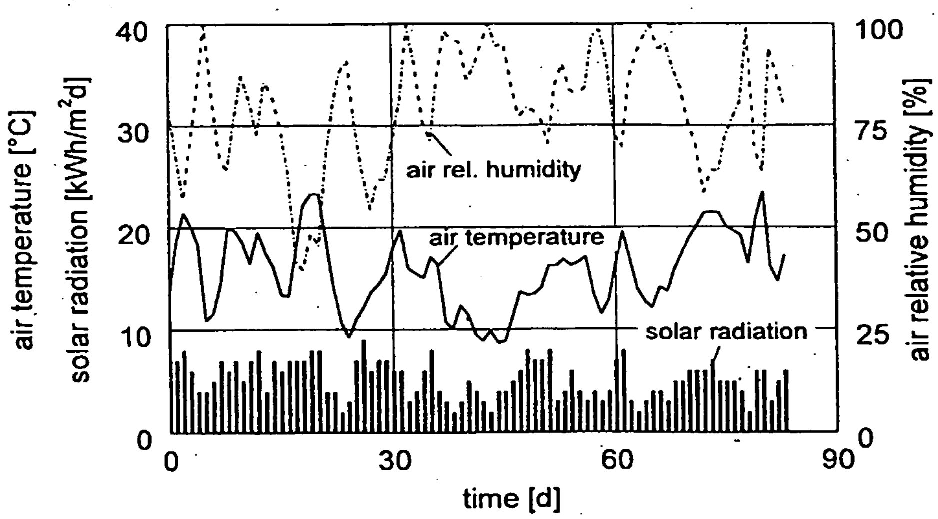

Figure 2. Climatic conditions during solar drying of municipal sewage sludge in Renquishausen (FRG).

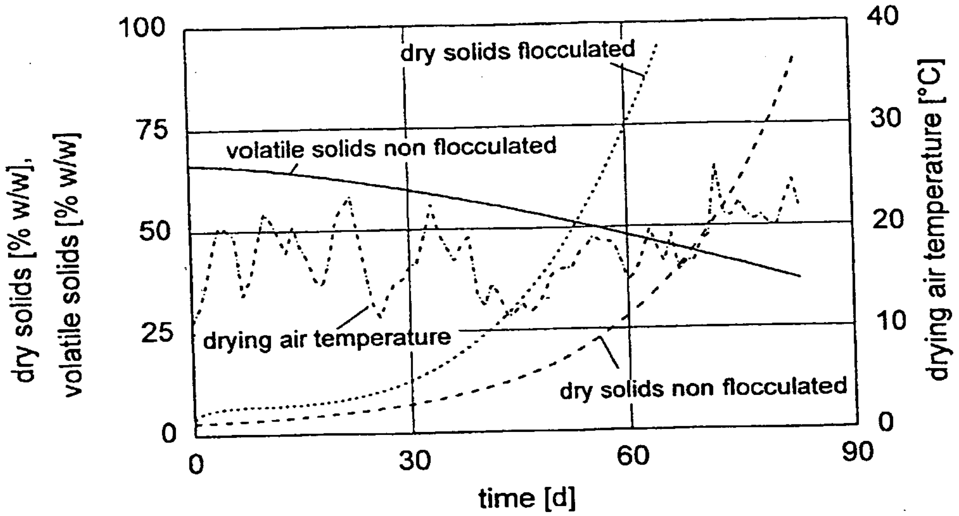

Figure 3. Course of the dry solids (ds) and the volatile solids (vs) content during solar drying of municipal aerobically digested sewage sludge at a load of 425 l/m^2 in Renquishausen (FRG).

decreased to 34% w/w, which corresponds to a reduction of 48%. The dry sludge is therefore considered to be completely stabilized and from this point of view suitable for all ways of disposal (8).

During the drying process, the microprocessor of the plant controlled automatically the "electric mole" according to the climatic conditions and the dry solids concentration of the sludge. The minimum operation time of the "electric mole" was 3 h a day and the maximum was 13 h. That means an average operation time of 5 h per day.

Figure 4 shows the consumption of solar and electrical energy for evaporation of water and mixing, aerating and turning of the sludge. The sum of the solar radiation falling on the surface of the sludge during the experiment was 309 and 237 kWh/m^2 for the nonflocculated and flocculated sludge, respectively. This corresponds to a specific thermal energy consumption of 749 kWh per ton of evaporated water for the nonflocculated sludge, and 573 kWh/t for the flocculated one. Compared to the thermal energy consumption of conventional dryers, which is reported in literature as 800 to 1000 kWh/t, these are relatively moderate values (3). Furthermore, the thermal energy consumption in the solar dryer was fully covered by solar energy and is therefore free of charge.

Comparing the global radiation on a horizontal surface outside the dryer and the sludge surface it was found that the average total transmission losses caused by the air-bubble foil were 37%.

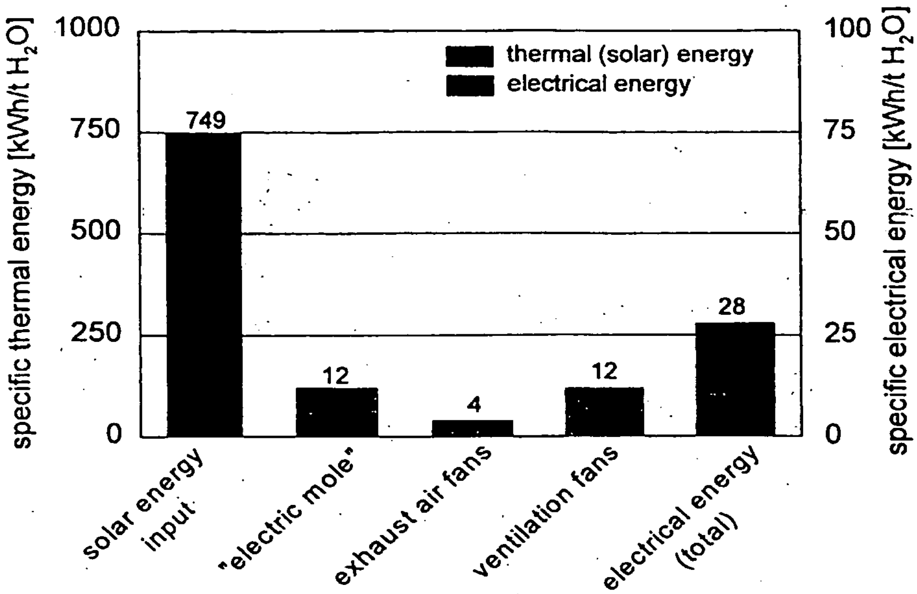

Figure 4. Consumption of solar and electrical energy during solar drying of sewage sludge in Renquishausen (FRG).

Looking at the electrical energy input, the specific energy consumption was 28 kWh per ton of evaporated water for the nonflocculated sludge and 22 kWh for the flocculated sludge. Compared to 70–110 kWh/t during thermal drying, this is also a moderate value (10). Half of the total amount was consumed by the "electric mole" whereas the other 50% were used to run the fans.

CONCLUSIONS

Solar drying of sewage sludge has several advantages compared with other sludge treatment processes like mechanical dewatering or thermal drying especially for small to medium sized sewage plants. The achieved high volume reduction of up to 97% by drying leads to a reduction of the transportation, handling and dumping costs. Depending on the site characteristics and the legal demands, the high dry solids content and the reduced total volatile concentration of the end-product opens additional pathways of disposal such as incineration or landfilling (compare 8). Furthermore the reduced volume reduces the dependence on a specific pathway of disposal or a certain disposer.

The use of an organic flocculant proved to be highly efficient when treating liquid sewage sludge with a dry solids concentration of 3%. The required drying time and the specific electrical energy consumption were reduced by almost 25%.

The achieved reduction of the volatile solids content by up to 48% guarantees the production of a completely stabilized sludge, meeting all existing legal requirements like the ones from the United States Environmental Protection Agency (EPA) (8). Therefore, the stabilization tanks for aerobic digestion do not have to be oversized for possible flow-peaks and the electrical energy consumption for aerobic digestion can probably be reduced.

Due to the moderate investment, the low energy consumption of less than 30 kWh per ton of evaporated water and the flexibility concerning the utilization and disposal of the end-product solar drying of sewage sludge is a highly interesting technology for small to medium sized sewage plants.

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